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EXPERIMENTAL RESEARCH ON THE INFLUENCE OF SOAKING AGING TYPE ON SOME MECHANICAL PROPERTIES OF THE ALLOY AlZn5,7MgCu

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The paper presents results of experimental laboratory-scale research on the influence of the AlZn5,7MgCu alloy thermal processing mode. Two types of aging heat treatment were studied, namely: a natural aging and an artificial aging treatment. For each of the two types of technological heat treatment, the change of the mechanical properties was monitored according to the parameters of the aging procedure.

The experimental research of this paper highlights the advantage of artificial aging as compared to natural aging, but this advantage must also be seen in terms of the costs implied by the two types of treatment.

Key words: aluminum alloy, heat treatment, time-temperatura, mechanical properties, microstructure.

INTRODUCTION

There is a close relationship between the development of the aviation industry and the evolution of the materials it uses. It is well known that this top area of the technique requires advanced materials with special physical and mechanical properties [1].

AlZn5,7MgCu alloy is part of AlZnMg Cu system special aluminum alloys, Zicral type. These alloys have high mechanical characteristics and low density, which is why they added interest to the aviation industry and machinery industry [2-7].

In the rough molded state, in general, these alloys have a low mechanical strength and deformability which change greatly by applying heat treatment [8].

The phase transformations in the solid state occurring during thermal processing, if they are allowed in the equilibrium diagram of the alloy, are an essential condition for achieving a heat treatment by implementing solution quenching and artificial or natural aging on an aluminum alloy. An alloy of this type is one that can support an order-disorder reaction. The high strength of Al-Zn-Mg-Cu alloys is directly proportional to the increase of the amount of Zn or Zn + Mg content, thus generating fine precipitates metastable zones, rich in Zn and Mg, which represent the so-called GP zones [9].

The stages of the hardening mechanism of the structure after applying heat treatments of aging are: forming the supersaturated solid solution by applying solution quenching, formation of Guinier - Preston areas during the aging process; first precipitates form a metastable zone (η'), then, as the temperature gradient is higher, these areas become stable (η), the formation of $MgZn_2$ precipitates [10].

M. I. Neacșu , A. Chiriac, "Dunarea de Jos" University of Galati, Romania
E. R. Chiriac, University of Medicine and Pharmacy Bucharest, Faculty of Pharmacy, Romania
O. Pandia, University of Agricultural Sciences and Veterinary Medicine Bucharest, Romania
I. Saracin, University of Craiova, Faculty of Agriculture, Romania.

MATERIALS AND METHODS

The materials for the experimental research are samples of the AlZnMgCu system alloy, whose chemical composition is shown in Table 1. The chemical composition of the alloy studied falls within the requirements of EN 573-3-2013 [11].

Table 1 **Chemical composition of the researched alloy / mas. % [11]**

Zn	Mg	Cu	Si	Fe	Cr	Mn	Al
5,76	2,61	1,55	0,15	0,19	0,19	0,1	Remainder

In order to be used in the aviation industry or in the car industry, this alloy must acquire, after applying thermal processing regimes (natural or artificial aging), the mechanical properties prescribed in EN 485-2-2013 [11], which are those shown in Table 2.

Table 2 **Alloys properties [12]**

R_m / MPa	$R_{p0,2}$ / MPa	A_5 / %	HB
540	470	7	161

In this paper, it was experimentally investigated the influence of some heat treatment regimes on the mechanical properties of the AlZn5,7MgCu alloy.

Experiments have been conducted in two technological thermal processing variants: variant I, which is represented by the natural aging, and variant II, which is the artificial aging regime.

Ingot casting was performed on the casting system of SC Wagstaff Alro Slatina S.A., Romania. Alro in SC S.A. was performed the homogenization treatment of the ingots at a temperature of 480 °C in an Olivotto semi working oven, which works within the temperature range 460 - 610 °C.

Heating the samples with a view to hot rolling at a temperature of 435 °C, hot plastic deformation with a reduction rate of 25 %, heating the samples at 500 °C for solution quenching and warming the samples to artificial aging temperatures were conducted in the Laboratory of Metal Forming and Heat Treatment of the Faculty of Engineering of "Lower Danube" University of Galati. These technological operations are common for both variant I and variant II.

The temperatures of artificial aging are: T_1 = 120 °C, T_2 = 140 °C, T_3 = 160 °C, T_4 = 180 °C, T_5 = 200 °C with the residence time of: τ_1 = 4 hour, τ_2 = 8 hour, τ_3 = 12 hour, τ_4 = 16 hour, τ_5 = 20 hour for each temperature.

Research variant I aimed, for a degree of hot plastic deformation ε = 25%, the influence of the duration of maintaining the natural aging for τ_1 = 24 hours, τ_2 = 72 hours, τ_3 = 168 hours, τ_4 = 360 hours, τ_5 = 720 hours, τ_6 = 1080 hours, τ_7 = 1440 hours on the mechanical properties studied.

Research variant II has sought, for a degree of hot plastic deformation ε = 25%, the effect of temperature and duration of keeping at the artificial aging on the mechanical properties studied. After the hot plastic deformation, the sample dimensions had the following values: length = 150 mm; height = 5 mm; width = 60 mm.

RESULTS AND DISCUSSIONS

After thermo mechanical treatment, the samples were subject to thermo mechanical testing as a result of which the mechanical characteristics were determined: R_m, $R_{p0,2}$, A_5, HB. On the basis of these findings, there have been made the graphs of mechanical properties variation depending on the aging temperature and time.

Figure 1 shows the variation in resistance properties according to natural aging time and it can be noticed that these mechanical properties increase as the natural aging time increases, up to a maximum amount corresponding to a time of 1 080 hours.

The graph in Figure 2 shows that the elongation at break decreases as the natural aging time increases and records a minimum at the time of 1 080 hours, followed by a slight increase. For the tensile properties, as well as for elongation, this variation can be explained by the fact that the precipitates formed during the natural aging process have reached a critical value of their size, after which their growth by coalescence followed.

In Figures 3, 4, 5, 6 are shown the variations in properties of the studied alloy, according to variant II experimental research.

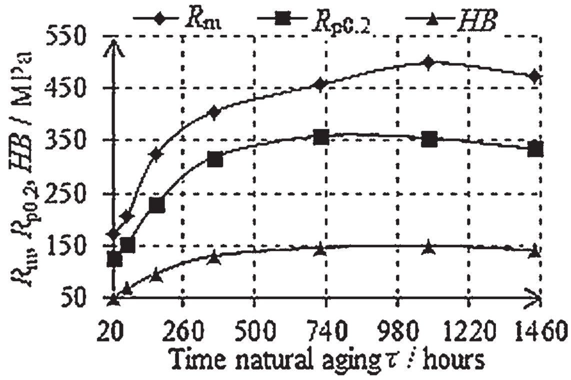

Figure 1 Variation of R_m, $R_{p0.2}$, HB during natural aging

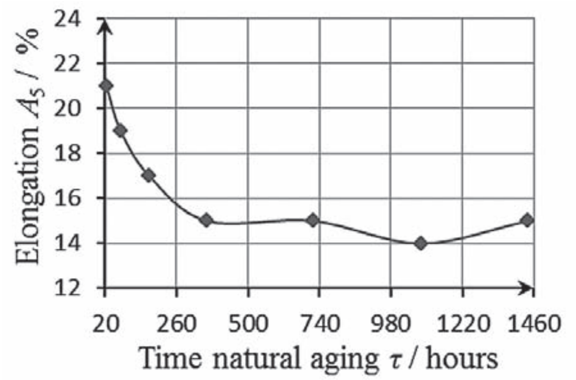

Figure 2 Variation of elongation at break with natural aging time

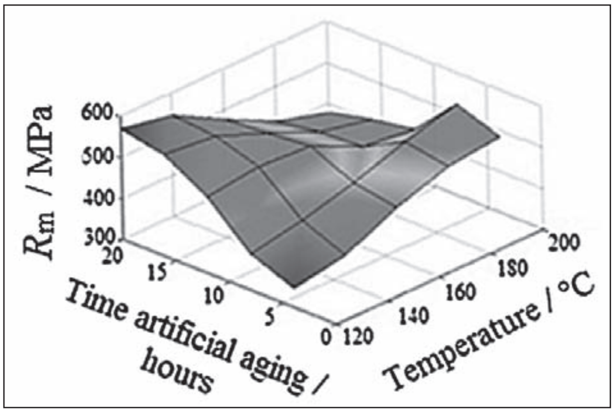

Figure 3 Mechanical resistance variation with artificial aging temperature and time

For properties R_m, $R_{p0,2}$, HB was found an increase in their values with the increasing of the duration of treatment at temperatures of 120 and 140 °C.

The thermal regime at temperatures of 180 to 200 °C and a duration of 8 hours, lead to maximum values of the mechanical characteristics.

As the aging time increases above this value, the mechanical properties decrease. The temperature of 160 °C leads to mechanical resistance values that increase with the increasing of the treatment time, up to a period of 12 hours, after which a decrease in mechanical properties can be seen.

The highest value for A_5 is obtained at 200 °C and a treatment time of 20 hour.

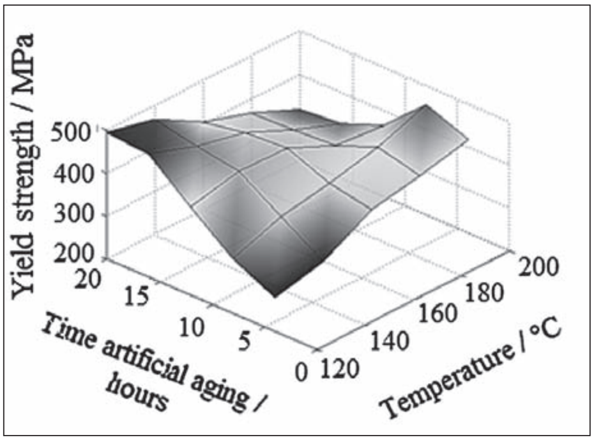

Figure 4 The variation in yield strength with artificial aging temperature and time

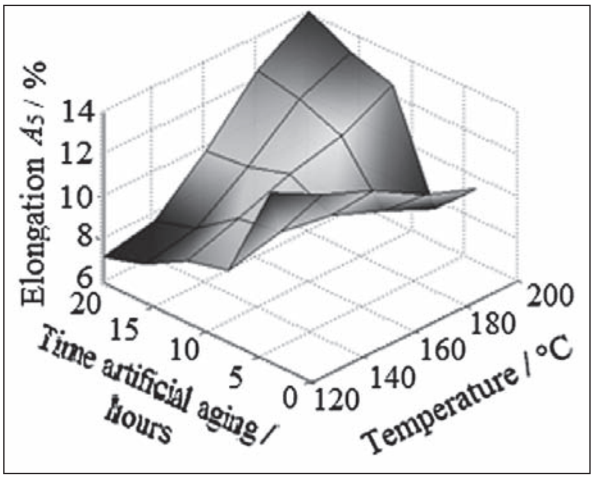

Figure 5 Variation of elongation at break with artificial aging temperature and tim

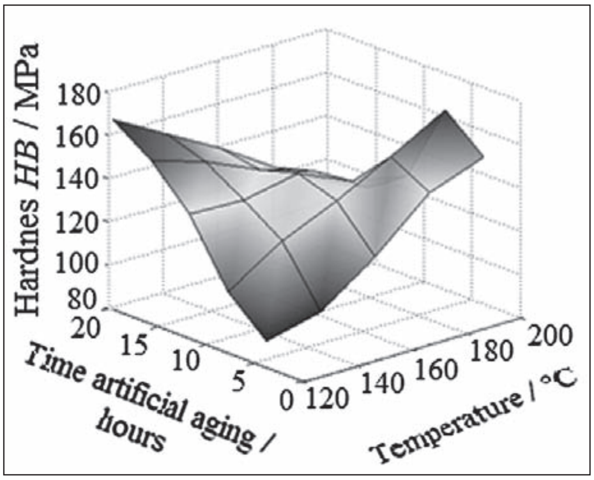

Figure 6 HB hardness variation with artificial aging temperature and time

Figure 7 shows the microstructure of the alloy that was submitted to natural aging for 729 hours, and where the formed precipitates on the basis of Al, Zn and Mg, leading to hardening of the material, are observed.

Figure 8 shows the microstructure of the alloy after it has been artificially aged at 140 °C and a time of

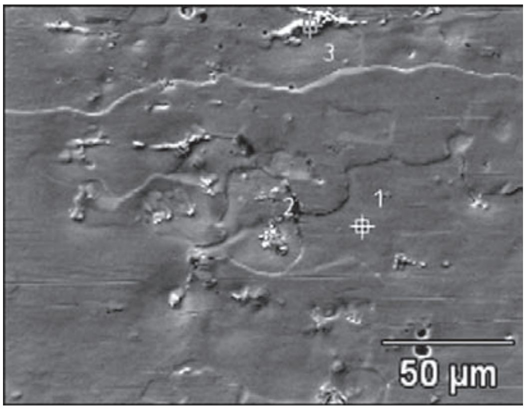

Figure 7 Natural aging microstructure (τ = 720 / hours), magnification 1509: 1

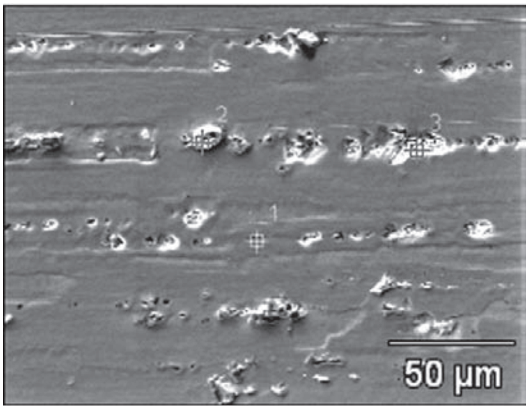

Figure 8 SEM electron microscopy of the studied material subjected to variant II treatment at 140 °C and a time of 8 hour, magnification 1448: 1

8 hour. By comparing the two images, it can be observed that after artificial aging, the number of precipitates is larger and they are more finely dispersed in the base matrix of solid solution α, as compared to those formed by natural aging.

CONCLUSION

After conducting experimental research the following conclusions can be drawn:

– The mechanical properties of the alloy continuously vary with the temperature and duration of aging;
– The allure of the properties variation curves at aging shows that the maximum values of one of the desired properties decreases as the temperature or duration rises above the optimum value; approximately the same values of a feature can be obtained either at higher temperatures and shorter durations, or at lower temperatures and longer durations);
– Increasing the temperature of aging or durations extending over a certain amount decreases resistance properties, but gives good dimensional stability and properties;
– Of the two types of heat treatment researched, the best mechanical resistance properties were obtained after the artificial aging regime;

– The properties required by EN 485-2-2013 for the studied alloy are met for only some thermal processing parameter values in the variant II.

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Note: The responsible translator for English language is Bujor Cornelia, official English and French interpreter and translator under license no. 23 306 / 2008 issued by the Romanian Ministry of Justice, Romania